LIV.DATA NEWS

Issue 01 | March 2024

WELCOME

I am absolutely delighted to launch this inaugural edition of LIV.DATA NEWS - a newsletter designed to share groundbreaking research outcomes and connect the data science community.

Our newsletter will keep you up to date with research results from our LIV.DAT and LIV.INNO STFC Centers for Doctoral Training, news from our students and partner organizations, as well as our many events. It will also cover cutting-edge R&D in the wider community to share knowledge and best practice.

Welcome to LIV.DATA NEWS!

Prof Carsten P. Welsch
Coordinator

Supernova model discrimination with a kilotonne-scale water Cherenkov detector

LIV.DAT student Adam Tarrant works on developing water Cherenkov detectors which are used to detect neutrinos. One of these detectors is the proposed WATCHMAN detector and a paper recently published in the Journal of Cosmology and Astrophysics explores how this detector can be used to discriminate between different supernova models by looking at neutrinos spectrum for a core collapse event.

WATCHMAN, a cylindrical kilotonne-scale water Cherenkov detector, has been developed to detect reactor antineutrinos through inverse β-decay for non-proliferation applications but also has the ability to observe antineutrino bursts of core-collapse supernovae within our galaxy.

Detector configurations with sizes ranging from 16 m to 22 m tank diameter and 10% to 20% photo-multiplier tube coverage were used to compare the expected observable antineutrino spectra based on the Nakazato, Vartanyan and Warren supernova models. These spectra are then compared to each other with a fixed event count of 100 observed inverse β-decay events and a

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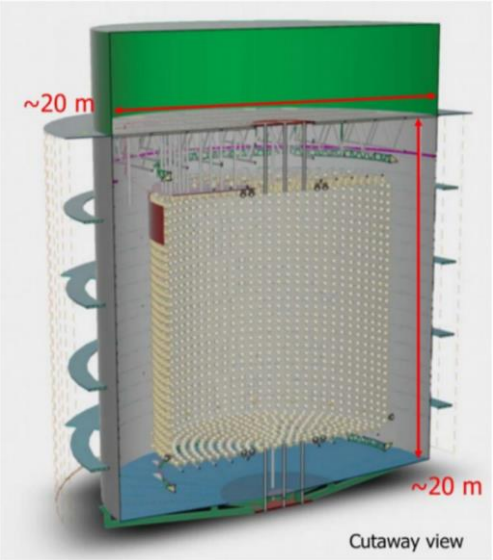
benchmark supernova at 10 kpc distance from Earth. By comparing the expected spectra, each detector configuration's ability to distinguish between them was evaluated.

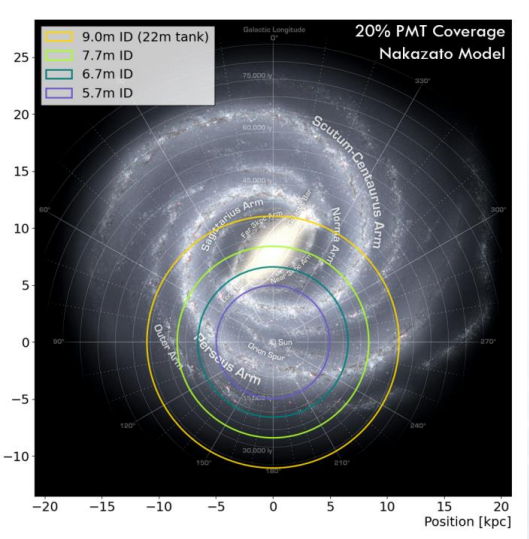


Schematic cutaway view of the WATCHMAN detector concept by Jan Boissevain (University of Pennsylvania), showing the outer tank wall, the array of PMTs and the inner volume enclosed by the PMTs support structure

It was demonstrated that the total fiducial volume and, by extension overall tank size, is the most important factor to its performance to observe and extract physics information from a core-collapse supernova. This study shows that an application-driven antineutrino detector of sufficient size (18 m or larger in diameter) in a low background environment is capable of making useful measurements at the commonly used benchmark distance of 10 kpc, a distance within which approximately half of the supernova progenitors in our galaxy can be found.

The analysis then demonstrates that the detector design is capable of meaningful event discrimination (90+% accuracy) with 100 observed supernova antineutrino events in most configurations. Furthermore, a larger tank configuration can maintain the performance at 10 kpc distance and above, indicating that overall target mass is the main factor for such a detector's discrimination capabilities. Additionally, the results show that the detector is capable of observing a significant number of events from a core-collapse supernova within the Milky Way. As a result, WATCHMAN is capable of acting as an early warning system, an important feature for the purpose of multi-messenger astronomy.

This study demonstrates that, in addition to its original non-proliferation application, the WATCHMAN detector concept is a useful multipurpose platform for ongoing fundamental physics and science collaboration. Furthermore, as this study shares its analysis and reconstruction tools with the reactor antineutrino-based tools, it highlights their versatility for use in liquid-based detectors but also means that a dedicated reconstruction optimised for supernova events may yield future improvement of these results.



Effective range of detector superimposed on the Milky Way, using the Nakazato model and a detector PMT coverage of 20% (right). Galaxy image reproduced from NASA/JPL-Caltech/R. Hurt (SSC/Caltech) CC BY 4.0.

More information:

Supernova model discrimination with a kilotonne-scale Gd-H2O Cherenkov detector', Y. Schnellbach, et al., JCAP01(2024)004 DOI: 10.1088/1475-7516/2024/01/004

LIV.DAT students Felix Soubelet and Gyanendra Yadav complete PhD

LIV.DAT students **Felix Soubelet** and **Gyanendra Yadav** have successfully defended their PhD theses.

Felix Soubelet's PhD looked at developing the optics for the high luminosity upgrade of the LHC. The beam parameters in HL-LHC need to be much more tightly controlled than in the original LHC so highly accurate modelling of the machine is required to optimise these parameters. Tools which automatically build models of the machine were used to aid this development work. Measurements of beam parameters in the LHC were taken then these were fed back in to the model to improve it further still. This process was continued until the required beam parameters were achieved in the model of HL-LHC.

Felix said "I enjoyed engaging with and being a part of the amazing science done at CERN. Participating in (sometimes my own) experiments in the control center was a highlight of my experience. I was surprised by the complexity of the LHC and consequently I was constantly learning about various parts or intricacies about it. I also think it is wonderful that people manage to create and operate something like this and I am amazed by the level of performance reached."

Since completing his PhD Felix has accepted a fellowship at CERN where he will continue to do the things he loves including maths, physics, software developments and machine experiments.

Gyanendra Yadav studied dielectric laser acceleration of relativistic beams and worked with colleagues from the Cockcroft Institute and PSI. The aim of his PhD was to extend DLA modelling and optimisation to high scientific impact experimental demonstrations and develop structures for experimental demonstration of acceleration and deflection at both the Paul Scherer Institute and CLARA at Daresbury.

While studying for his PhD Gyanendra got the exposure to work in an international collaborative atmosphere with the leading experts in his research field. He said, "The best thing about my PhD was being a part of the experimental demonstration of the simulations I performed and witnessing the challenges" Of his time studying he also said "The surprising thing for me was the extent to which machine learning or advanced computational techniques could be used in optimizing physical interactions"
Gyanendra undertook two internships as part of his PhD. Gyanendra said "The idea of doing an internship in the middle of my PhD was also useful as it diversified my skillset."

Gyanendra is currently designing advanced optical systems for Augmented Reality, working as an Optical Engineer in Cambridge, U.K.

Second cohort of LIV.INNO students start their PhDs

The second cohort of LIV.INNO students have started studying for their PhDs at the University of Liverpool and Liverpool John Moores University. Another eleven students from across the world have come to Liverpool to study a wide range of topics that have Data Intensive Science at the core of them. While some of the students will remain in Liverpool for the duration of their studies, others will spend time at other institutions such as CERN and Fermilab.

The students are about to commence their training in data science as well as subjects relevant to their projects such as accelerator physics, particle physics, astrophysics and nuclear physics. As well as continuing their studies in these subjects the students will receive training in research skills and techniques, project management, networking, communication and presentation skills, with the aim to provide all students with the skill set required for a future career in academia or industry.

Each student is also required to undertake a six-month industrial placement as part of their PhD. This gives them the opportunity to apply their data science skills to real world challenges while gaining knowledge and experience working outside academia.

The projects the new students are working on are from across the three **LIV.INNO work packages**. The projects range from studies at Fermilab and CERN to modelling the effect of black holes on their host galaxies to studies of phenomena at the boundary of our current knowledge of particle physics. More information about the students and their projects can be found **here**.

We wish all the students well in their studies and welcome them to the LIV.INNO project!

LIV.INNO student awarded Alan Turing PhD Enrichment scheme placement

LIV.INNO student Andrea Sante

LIV.INNO student Andrea Sante, who is studying 'Reconstructing the assembly history of our Galaxy using neural networks', at the Astrophysics Research Institute at Liverpool John Moores University has been awarded an Alan Turing PhD Enrichment scheme placement.

The Enrichment scheme is designed to give students the opportunity to enhance, refresh, and broaden their research with the Turing's community and in recognition of their place within the UK's growing data science and Artifical Intelligence research community. Placement Award holders receive funding to physically access the Institute's facilities whilst also building both online communities and facilitating other activities such as attending training courses, going to conferences and visiting collaborators.

Enrichment students have the opportunity to find new collaborators for their research or related work. Enrichment Awards allow students to join a cohort from across the UK, as well as the range of researchers already active at the Turing. Collaboration and networking are encouraged at the Institute through interest groups, seminars, events and workshops and engagement with the Turing's research programmes.

Andrea said, "I feel very privileged to have the opportunity to spend part of my PhD in the national centre for data science and AI. I am looking forward to join the Turing community and to delve deeper into the applications of machine learning to the study of galaxy formation. I strongly believe it will be a huge formative experience."

The Alan Turing Institute offer a wide variety of training for PhD students who are using data science and Artificial Intelligence in their studies. LIV.INNO students are encouraged to take up these opportunities where they are relevant to their particular project.

Prof Carsten Welsch to co-chair EIC Accelerator Collaboration

The Electron-Ion Collider (EIC) partner host labs, Brookhaven National Laboratory and Jefferson Lab, have announced Professor Carsten P Welsch, Head of Liverpool's Accelerator Science cluster based at the Cockcroft Institute, as co-chair of the EIC Accelerator Collaboration.

Professor Carsten Peter Welsch

LIV.DAT and LIV.INNO Director Professor Welsch has a broad experience in accelerator physics and technology, and in establishing collaborative environments with international participation. His research covers the development of advanced instrumentation, medical applications, data intensive science, antimatter physics, and novel high gradient accelerators. He has led numerous large scale international projects and is a member of a large number of advisory panels.

Professor Welsch will share his duties with Prof Andrei Seryi (Jefferson Lab and Old Dominion University). This leadership team will establish a formal international collaboration, rooted in the 2020 and 2021 EIC accelerator workshops, which attracted hundreds of participants from more than 20 countries, as well as numerous technical meetings with representatives from national and international institutions.

The construction of the EIC at Brookhaven National Laboratory marks the establishment of a world-leading facility for nuclear physics. The design, construction, and future upgrades of the EIC will have many exciting scientific and technical challenges, creating opportunities for a worldwide accelerator collaboration to become part of this exciting venture.

The EIC will be a particle accelerator that collides electrons with protons and nuclei to produce snapshots of those particles' internal structure—like a CT scanner for atoms. The electron beam will reveal the arrangement of the quarks and gluons that make up the protons and neutrons of nuclei. The force that holds quarks together, carried by the gluons, is the strongest force in Nature. The EIC will allow us to study this "strong nuclear force" and the role of gluons in the matter within and all around us. What we learn from the EIC could power the technologies of tomorrow.

The EIC Accelerator Collaboration will benefit the EIC project, its collaborating partners, and the wider community of accelerator experts. Furthermore, it will play an important role in enhancing the developments of the evolution, upgrades, and the ultimate performance of the EIC facility.

The collaboration kick-off meeting will be held as a satellite meeting at the IPAC2024 conference in May 2024 in Nashville, TN, USA.

Further information about the EIC: https://www.bnl.gov/eic/

Data Science Fellow Interview

In each edition of this newsletter, we will interview one of our Data Science Fellows from the LIV.DAT CDT, which recruited students from 2017 to 2020. In this edition, we speak to Magda Satrazani who has been studying 'Shapes studies in neutron-rich cerium isotopes' during her time at the University of Liverpool.

What attracted you to the LIV.DAT CDT? Has it fulfilled your expectations?

The LIV.DAT group offers the possibility of being part of a great network of experts in the field of physical sciences and industry.

The seminars, that were organised frequently, were very enlightening and have contributed significantly in broadening my knowledge in applied physics. As a PhD student at the University of Liverpool, I found this a unique opportunity to expand my ideas in different analysis techniques ,than the ones I am more familiar with, and to meet some very inspiring people. I also had the chance to interact with other members of the LIV.DAT community and share interesting ideas. Being part of this team has definitely fulfilled my expectations.

Can you explain in a few words what your project was about and what you have achieved?

My research topic concerns the structure and shape of atomic nuclei, particularly with respect to radioactive isotopes that have an excess of neutrons, so-called neutron-rich nuclei. The constituent particles of the atomic nucleus, namely protons and neutrons, combine in different numbers to produce all known isotopes, with about 300 or so being stable and observed all around us. There are however another 3000 unstable isotopes that are known to exists with half-lives ranging from billions of years down to just a few microseconds. These isotopes undergo a range of different decay modes, most predominately beta-decay, which converts a proton in to a neutron with the emission of an electron, or vice-versa with the emission of a positron, depending on which particle is in excess.

In my research, I take advantage of this decay to study the structure of the daughter nucleus, which further decays with the emission of gamma-ray radiation. I am particularly interested in studying the energy and intensity distributions of these gamma-rays as a route to understanding the shape of the nucleus. It has been proposed that nuclei can have exotic deformation modes, not just being spherical or rugby-ball shaped, but even taking the form a pear. I have performed experiments at the TRIUMF Radioactive Ion Beam Facility in Vancouver, Canada to investigate this phenomenon in isotopes of the element cerium.

Currently, I am at the final year of my PhD studies and have managed to acquire some very interesting results on the energies and electromagnetic properties of the gamma-rays being emitted from the isotopes 146,148,150Ce. Especially for the 150Ce isotope, it is the first time that it is proven, though spectroscopy

techniques, that its shape is indeed deformed and resembles to that of a pear.

What has the CDT provided you professionally?

Through the CDT I had the chance to be introduced for the first time to the industry world and consider other paths and applications of nuclear physics. It made me consider more options of research and has provided me with a broad network of people, all of them welcoming and happy to answer questions and help.

Can you say something about your next career move?

I am expecting to submit my thesis this spring and I would very much like to stay in the field of research and to do what I love the most. Experimental nuclear physics of course! I have been recently offered a Postdoc position in the Nuclear Spectroscopy and Nuclear Reactions group at KU Leuven in Belgium, and about to start working on a very challenging and interesting project. Can't wait!

What is your favourite memory from your time as part of the CDT?

My favourite memories from my time as part of the CDT are definitely the workshops, mini-conferences and events organised throughout the years. They were a wonderful opportunity to present my work in a wider audience, and during all the social activities we had fun and shared nice moments.

Joint LIV.INNO and EuPRAXIA-DN researcher training hosted in Liverpool

Participants at the researcher skills school.

Cutting-edge postgraduate researcher training schemes guarantee international competitiveness of the researchers trained and provide them with the necessary skills for a future career as researcher in either the academic sector or in industry.

CDT Director Prof Carsten P Welsch has been leading large-scale PGR training schemes for more than a decade. As past chair of STFC's Education Training and Careers Committee and member of the UKRI Talent and Skills Advisory Group, he has held key roles in defining and continuously improving PGR training in the UK and beyond.

Together with his project partners and members of his project TEAM based at the Cockcroft Institute, he organized an interdisciplinary 5-day training for researchers in the EuPRAXIA Doctoral Network and the LIV.INNO Center for Doctoral Training. This researcher skills school took place in Liverpool between 13 – 17 November 2023 and was designed for the particular needs of the researchers in these two programs, focusing on synergies, networking opportunities and possible collaboration.

The concept for this course was developed by Professor Welsch during the delivery of his previous training networks, praised in formal project reviews as ‘best practice’ in Europe. The School featured project-specific and general-skills parts. After an icebreaker exercise on Monday morning and an introduction to presentation skills training, the importance of scientific writing was covered by Kate Kahle from CERN’s media team. Her session familiarized participants with different writing styles required by specific journals, media and as part of scientific outreach.

The theory of project management was introduced on day 2 by Dr Fraser Robertson of Fistral. Participants were asked to develop a detailed project plan for their PhD projects which will feed into structured career development plans they all have to establish at the start of theirPhDs. The importance of peer review was covered on that day by Dr Eva Villela, a UKRI Future Leaders Fellow in our department.

Presentation skills training at Daresbury Laboratory.

On Wednesday, the training moved to Daresbury laboratory. Presentation skills sessions in the morning required all participants to give short presentations about their PhD projects in small groups. These were video-recorded and then reviewed critically with detailed feedback provided by the presenter, their peers and professional trainers to identify best practice whilst giving every participant the opportunity to identify a presentation style that works best for them. In the afternoon, colleagues from STFC/ASTeC offered tours of their cutting-edge labs and gave an overview of the many R&D activities they are involved in.

To promote group work and discussion between participants, small groups were asked to develop a proposal that seeks funding for innovative outreach demonstrations that can be used to fascinate diverse audiences for the science and technology of EuPRAXIA-DN and LIV.INNO. Participants developed a grant application throughout the week for these demonstrations. This included resource planning, stakeholder identification, marketing and characterization of potential impact. Through their proposal and a group presentation, they competed against the other teams.

In addition to the above, sessions on mental health by Alexander Drake and Barry Farrington from the Mental Health Advisory Service and on a look back on their time as LIV.DAT PhD candidate by Dr Alexander Hill completed an intense week.

Professor Welsch said: “It was fantastic to have all doctoral candidates together during this week and to have very focused discussions on how they can get most out of their projects, as well as the opportunities that are in collaboration with other school participants. It was intense, enjoyable and very forward-looking. Many thanks to all of the trainers, my project TEAM, and of course the early stage researchers for engaging with the many activities that were on offer.”

A final year skills training, focusing on the transition to the international job market after graduation, will be offered to all school participants in 2026. This will again be hosted in Liverpool.

Bridging Academia, Industry and Government: Naimuri's Data Scientists Share Insights

In October, the Department of Physics had the pleasure of hosting Dr James Ramsden and Dr Zac Baker, senior data scientists from Naimuri, as part of the LIV.INNO Data Forum series. This series is designed to introduce the PhD students of the doctoral program to individuals who have transitioned from academia to industry or work in fields that students may wish to pursue.

Naimuri is a subsidiary of QinetiQ, specialising in delivering data and technology solutions for clients in government and law enforcement. Located at MediaCity in Manchester, Naimuri employs nearly 200 professionals in data science, software development, cloud computing, and business management. They focus on providing research as a service and employing rapid prototyping to secure contracts.

Naimuri Data Science Forum at the University of Liverpool.

During the visit, Dr Ramsden and Dr Baker shared their backgrounds in Physics, including Dr Ramsden's PhD in quantum mechanics from York and Dr Baker's master's in radio astronomy from Manchester. Dr Baker also explained how Naimuri has grown from a 20-person organisation just two years ago to its current size.

In addition to their core activities, Naimuri facilitates engagement between academics and government agencies to ensure that UK policy and decision-makers have access to the latest techniques and resources developed in academia. They primarily aim to strengthen connections between government and universities in the North West, challenging the dominance of the 'golden triangle' cluster of universities in the south of England.

Naimuri's academic network encompasses more than 200 researchers across 90 disciplines and 20 institutions. Led by Dr Baker, Naimuri hosts regular Tech, Academia, and Government (TAG) events where academics propose solutions to challenges set by government departments, particularly in data management and natural language processing. These events often lead to participating academics being hired as consultants for government projects.

PhD students and other staff in attendance were eager to learn about the opportunities within Naimuri's network. They also found the information about Naimuri's ongoing projects, such as Uncertainty Quantification for Neural Networks and the use of Large Language Models in converting text to tabulated data, quite engaging.

Following the talk, there was extensive technical discussion about the optimal design of neural networks and the importance of ethics in designing intelligent systems for the public domain.

If you are interested in attending or delivering a Forum, please contact:

C. Astreos c.astreos@liverpool.ac.uk
Dr A. Hill a.d.hill@liverpool.ac.uk.

Lauryn Eley kicks off University of Liverpool's Data Science CDT Student Seminar Series

Lauryn Eley presenting ' X-Ray Imaging in Geant4 for Medical Applicaionts'.

Lauryn Eley kicked off the LIV.INNO CDT student seminars on Friday 20th October with her talk titled 'X-Ray Imaging in Geant4 for Medical Applications'. The subject of the seminar was Lauryn's PhD research into 3D x-ray imaging, with specific focus on the Adaptix digital tomosynthesis (DT) device. This device creates 3D x-ray images at lower dose and cost than achievable via competitor technology like CT, as well as being significantly more mobile.

The presentation began with an introduction of DT imaging concepts before shifting the focus to the theory of Monte Carlo Particle Transport (MCPT) codes. Geant4 was highlighted as a key example of an MCPT code, and the talk discussed how to utilise such a code for the desired simulations of the Adaptix DT technique. Example results from Lauryn's work up until now were included, and future research plans were also laid out.

More LIV.INNO student seminars have followed since with a seminar taking place each month covering a wide range of subjects with data science at their core including astrophysics, particle physics and nuclear physics.

Postgraduate students studying physics and other data science subjects from the University of Liverpool and Liverpool John Moores University are invited to attend these seminars.

Meet the LIV.INNO students

In each edition of this newsletter, we will introduce some of the students who are studying as part of LIV.INNO CDT

Lauryn Eley (2nd Year PhD student)

Project title:

Optimisation of low dose, low-cost mobile 3D X-ray imaging

Where are you from?

Aberdeen, Scotland, UK

What degree did you study?

An integrated Masters in Physics with Astrophysics from the University of York.

What do you do in your free time?

I have a range of interests including rugby (as a Scotland supporter, obviously), playing guitar, crochet, swimming and the gym.

Robert McNulty (2nd Year PhD student)

Project title

AI: from high energy physics to medical applications

Where are you from?

Liverpool, England, UK

What degree did you study?

I studied Physics MPhys at the University of Liverpool.

What do you do in your free time?

In my free time, I like to read, make things, and spend time with friends.

Katie Ferraby(2nd Year PhD student)

Project title:

Data analysis with deep learning technique and real-time event reconstruction in MUonE

Where are you from?

Birmingham, England, UK

What degree did you study?

I graduated from the University of Liverpool in 2022 with a Master's degree in Physics.

What do you do in your free time?

In my free time, I like to paint landscapes and read.

Andrew Jones (2nd Year PhD student)

Project title

Developing of instrumentation technologies for a future zero power reactor experiment on molten salt reactors

Where are you from?

Liverpool, England, UK

What degree did you study?

I completed a Master’s degree in Radiometrics with the University of Liverpool in 2021.

What do you do in your free time?

In my free time, I enjoy archery, working on classic cars and being out in the countryside.

Vacancies

Open positions connected to data science research:

University of Liverpool

Preparation and Characterisation of ‘Green’ Photocathodes for the Generation of High-Brightness Electron Beams

This project will focus on development of techniques to manufacture high-performance thin-film photocathode electron sources for particle accelerators, modifying and expanding the deposition equipment and processes as necessary

Competition funded PhD project.

Application deadline 31 March 2024.

Find out more and how to apply

Beam gas curtain monitor for the High Luminosity LHC

This PhD project will combine numerical studies using available commercial tools, as well as purpose-developed fluid dynamics and Monte Carlo tools to study the gas jet dynamics in various configurations. In addition, machine learning will be applied to optimize data analysis.

This project will be funded for 4 years with years 1 and 4 based in the UK. During this time a standard UKRI stipend will be paid. You will spend years 2 and 3 at CERN, and during this time, you will receive a CERN doctoral scholarship.

Application deadline 31 March 2024.

Find out more and apply

For more information about the PhD projects, please contact Prof Carsten Welsch c.p.welsch@liverpool.ac.uk

Dates for your Diary

Liverpool Virtual Seminar Series on Data Intensive Science			
9 April 2024	15:30 BST	Numerical simulations of spacetime and the role of HPC	Katy Clough (Queen Mary University of London)
7 May 2024	15:00 BST	Rigorous results from machine learning	Fabian Ruehle (Northeastern University College of Science)

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Liverpool Virtual Seminar Series on Data Intensive Science

The seminars in this series cover R&D outside of the LIV.INNO centre's core research areas and give an insight into cutting edge research data intensive science.

To register to attend these seminars please visit
https://indico.ph.liv.ac.uk/e/data_science_seminars

LIV.INNO

www.livinno.org

LIV.INNO Director

Prof Carsten P. Welsch
c.p.welsch@liverpool.ac.uk

LIV.INNO Project Manager

Naomi Smith
naomi.smith@liverpool.ac.uk

LIV.INNO Content Design & Communication

Alexandra Welsch
awelsch@liverpool.ac.uk